THE DISTRIBUTION OF FUTURE WHITE SETTLEMENT*

A WORLD SURVEY BASED ON PHYSIOGRAPHIC DATA

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With the passing of many purely artificial military and political boundaries we may look with more certainty to a time when the unrestrained economic resources of a region shall be the controlling factors in determining its prosperity and the density of its population.

For the past ten years the writer has been engaged on economic physiographic research in regard to the continent where such problems are presented in their simplest form. In Australia we are free from the presence of an alien racial element, and our climatic controls are relatively simple and are not confused by great topographic variation. At the same time a large range of climates, from the hottest tropical in the northwest to the cool temperate of Tasmania, affords a broad basis for comparative research.

In papers recently published[1] I have determined for Australia the temperature and humidity controls governing white settlement and the temperature and rainfall controls determining the economic limits of the main industries. On these bases I constructed a map showing how the future settlement of tropical Australia might reasonably be expected to be distributed.

The present paper is an attempt to carry out a similar investigation for the world as a whole and so to deduce the economic status of the continents including Australia. I have confined my study to the so-called white race, i.e. Europeans and their descendants, because data as to its climatic controls are available. This is not the case, so far as I am aware, with regard to the Mongolian or Negro races.[2] The white race has no opportunity or wish to supplant the yellow or black races in a broad belt of the Old World extending from Liberia to Japan, a limitation indicated by the boundaries in the map of future populations (Fig. 8). I have, however, thought it of

* I have to thank Professor Skeats for reading the manuscript and making many helpful criticisms.

[1] Griffith Taylor: The Control of Settlement by Humidity and Temperature, *Commonwealth Bur. of Meteorol. Bull., No. 14*, Melbourne, 1916.

Idem: Geographical Factors Controlling the Settlement of Tropical Australia, *Queensland Geogr. Journ.*, Vols. 32–33, 1918, pp. 1–67; abridged in *Geogr. Rev.*, Vol. 8, 1919, pp. 84–115. See especially the map (Fig. 23 in the abridged version) of potentialities of settlement in tropical Australia.

[2] I use the terms "white" race and "Mongolian" race in their generally accepted usage. There is, however, no doubt in my mind that the *Alpine* Europeans are closely akin to many so-called Mongolian, Indonesian, Polynesian, and Amerind peoples; while the other "white" races have millions of close ethnical relations in America, Malaya, etc. I have developed this thesis of migration zones in "Climatic Cycles and Evolution," *Geogr. Rev.*, Vol. 8, 1919, pp. 289–328, and "The Evolution and Distribution of Race, Culture, and Language," *ibid.*, Vol. 11, 1921, pp. 54–119.

interest to carry my investigation into these debarred regions, though here the results are outside the realm of practical geography.

The problem falls into three divisions. First, it is necessary to decide on the major controls which determine white settlement. Secondly, we must assign relative values to these several controls. Thirdly, we must classify the many diverse regions of the world, so that each unit shall be capable of quantitative consideration in terms of the controls determined upon.

My method has been as follows. I have subdivided the continents into economic regions. Each of these regions is tabulated in terms of what seem, in the writer's opinion, to be the four dominant controls (temperature, rainfall, location, and coal reserves). From these a quadrangular graph—the *econograph*—is constructed for each region. The area of this graph is found to represent approximately the habitability of the region concerned. Lines of equal habitability (isoikētes) are drawn on a map of the world. Using the present European populations as a criterion of reasonable saturation, it is shown that these isoiketes may be translated into isopleths of future population.

The map indicates that white settlement will tend to congregate around five world centers, or clusters of cities of a type which Geddes has named "conurbations." These are near London, Chicago, Sydney, Durban, and Buenos Aires. Of these the center in the United States will probably be the largest.

Economic Regions

In an investigation which contains so many variable factors the personal equation of the writer is bound to enter to some extent. The only way to counteract this is carefully to classify the regions involved and then to allot them economic values according to a fixed scale.

The economic regions which I have used, numbering 74 in all, are shown in Figure 1. These are much the same as Herbertson's natural regions[3] in the temperate zones. I have inserted the boundary between Europe and Asia; and, as the European plain varies so greatly in its economic resources, I have divided it into three units, approximately according to temperature. In Asia the Siberian belt is also separated into a western lowland and an eastern highland portion. The northern and southern halves of China differ greatly in resources and are subdivided. My studies of tropical Australia have led me to distinguish other types in the torrid zone, and it is here that I have modified Herbertson's regions most largely. Diverse topographies and differences in the rainfall types determined the subdivisions. The Saharan and Australian arid regions are divided in accord with the line separating the summer from the winter rain regions. This is, however, not of great economic importance. In North America the modifications are not marked. I have extended the Tundra region to the south; and on the

[3] A. J. Herbertson: The Major Natural Regions: An Essay in Systematic Geography, *Geogr. Journ.*, Vol. 25, 1905, pp. 300–312. The classification is carried further in "Oxford Wall Maps, Natural Regions," 1912.

east I have recognized three other regions, Eastern Canada and the Northeastern and Southeastern States.

The areas of these regions are given in the first column of Table IV. They were determined by planimeter and are approximate only. I have named the region in accord with the chief country or province included, but the economic and political boundaries rarely coincide.

Temperature Control

A glance at an ethnographic map of the world will show that temperature is the primary control in determining the distribution of the white race; but the optimum temperature and the upper and lower limits require considerable investigation. My own investigations have shown that a wet bulb temperature of 50° and a relative humidity of 75 per cent are near the optimum for the white race.[4] Unfortunately few countries publish wet bulb data, but the usual dry bulb reading under these conditions is close to 53° F. Huntington,[5] by an entirely different method, arrived at 60° F. as the best temperature for strenuous physical work and 40° for mental work. The upper temperature limit for fairly close white settlement seems to be about 70° F. (average annual temperature) or a little over. The chief "white" regions where such conditions obtain are in Brazil and northern Queensland. The chief control of the lower limit is economic rather than hygienic. The polar boundary of agriculture is not far from the annual isotherm of 30° F. We may therefore adopt these temperatures, 30°, 53°, and 70°, as critical values in our investigation.

Any world-wide study of temperature is greatly handicapped by the fact that published maps almost without exception show isotherms *reduced to sea level*.[6] This may be essential for forecasting, etc., but it makes the map almost useless for the economic geographer. Obviously it is not of much use to know that Tibet would have a temperature of 70° if it were at sea level, when actually the thermometer is usually below freezing!

In Figure 2 I give an approximation to the *actual* average annual temperature chart of the world. It is based on Buchan's map in Bartholomew's Meteorological Atlas, but is modified in accord with data in Hann's Handbuch der Klimatologie and elsewhere. The factor of 10° F. decrease with each 3,000 feet elevation has been used in calculating the temperatures. Little alteration is necessary in Europe and Australia, but Africa and especially Asia show striking convolutions in the isotherms.

The usual maps tend to give a wrong impression of inland Asia. We see that vast areas are too cold to have any value as areas of close settlement. On the other hand, there is a corresponding improvement in Africa, espe-

[4] Griffith Taylor: The Control of Settlement by Humidity and Temperature (discussed in the *Geogr. Rev.*, Vol. 4, 1917, pp. 401–403, and Vol. 5, 1918, p. 86).

[5] Ellsworth Huntington: Civilization and Climate, New Haven, 1915.

[6] A. J. Herbertson: Thermal Regions of the World, Oxford Wall Maps, 1909, shows mean actual temperatures (isotherms 32°, 50°, 68° F.) for January and July.

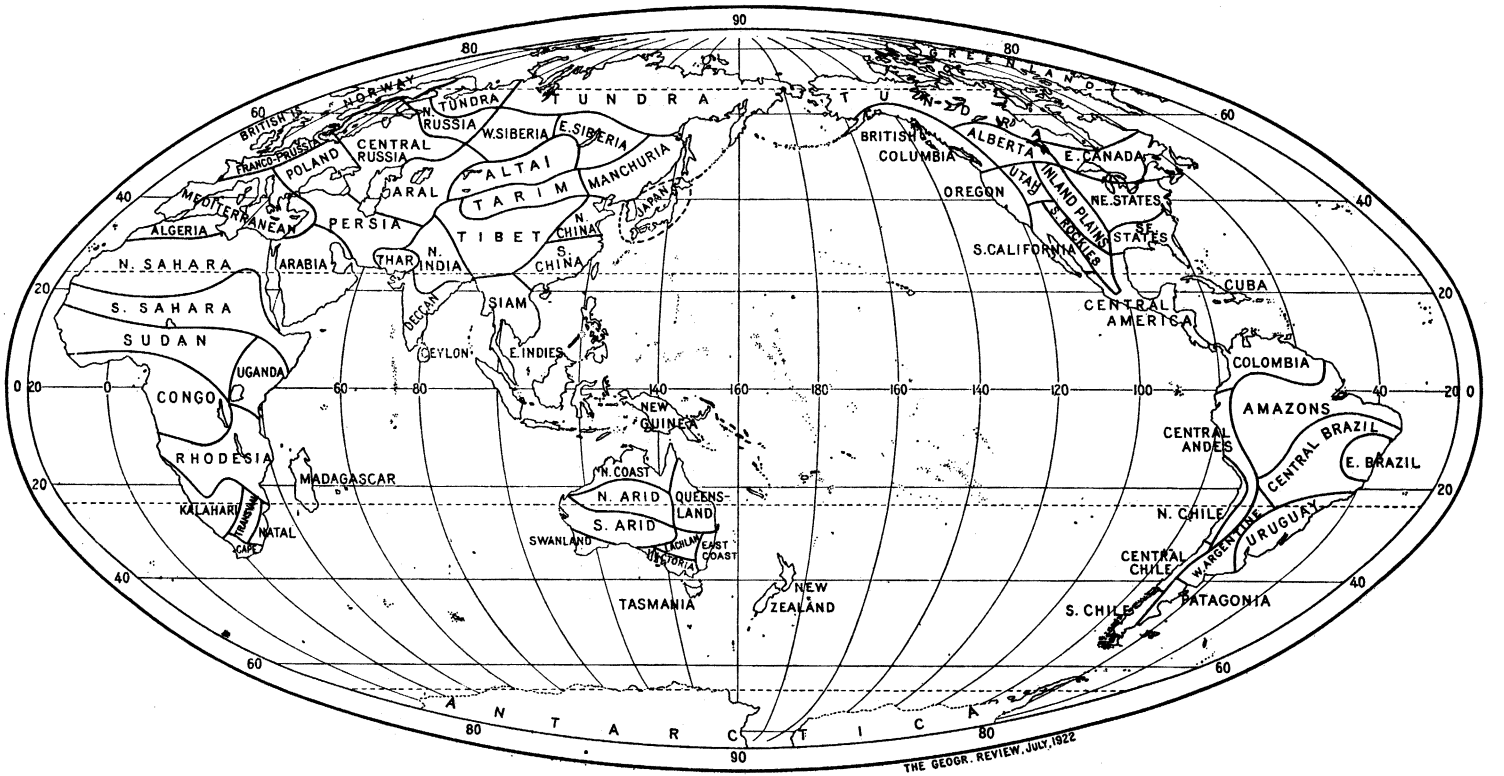

FIG. 1—Major economic regions of the world (boundaries partly after Herbertson). For the area and economic factors of the regions see Table IV.

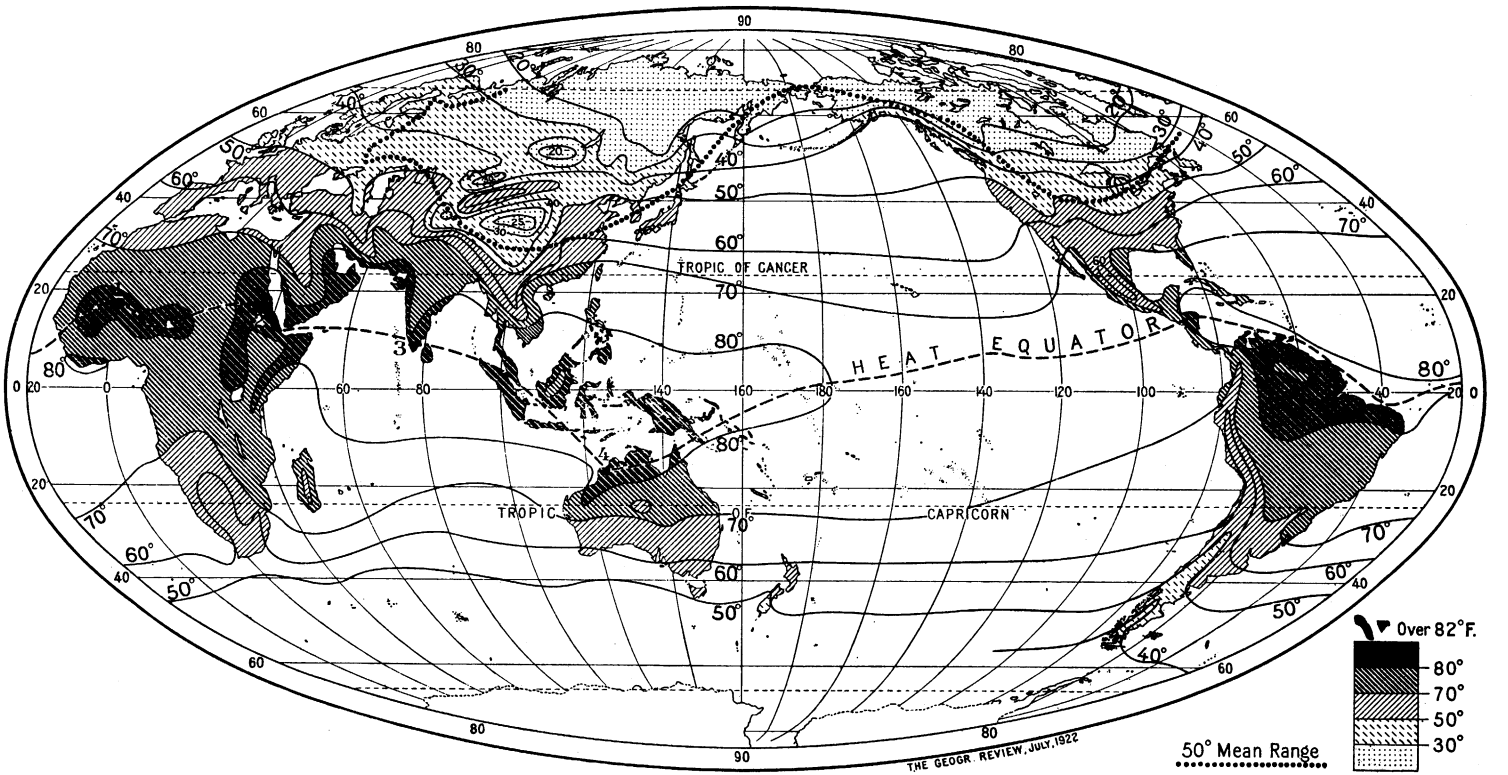

FIG. 2—Actual average annual temperature (i.e. not reduced to sea level). The region of great annual range of temperature (over 50°) is enclosed within the dotted line. The heavy broken line shows the heat equator passing through the four hottest regions of the world: 1, Timbuktu; 2, Massowah; 3, Tinnevelli; 4, Wyndham.

cially in the Rhodesian region, where a cool loop runs north nearly to the equator. The same feature is shown in the west of South America. An interesting feature is the course of the thermal equator. It runs far south in West Australia, through Wyndham (15° 30′ S.), one of the four hottest regions in the world and far hotter than anything to the north or south of it.

In Table I the areas in the various continents experiencing specified temperatures are given.

TABLE I—APPROXIMATE LAND AREAS WITHIN GIVEN TEMPERATURE BELTS

(*Unit, 1,000 square miles*)

VALUES	VIII	VI	IV	II	I	III	V	VII	Total
Temperature in degrees F.	Under 20	20–30	30–40	40–50	50–60	60–70	70–80	80+	
Europe	0	160	800	1,790	760	320	—	—	3,830
Percentage	—	4.0	21	47	20	8	—	—	
Asia	2,500	2,180	2,780	1,840	2,440	2,020	2,160	1,820	17,740
Percentage	14	12.2	15.6	10.4	13.8	11.5	12	10	
Africa	—	—	—	—	830	1,460	6,880	1,910	11,080
Percentage					7.5	13	62	17	
N. and Central America	2,400	1,360	1,200	1,360	1,140	1,500	320	70	9,350
Percentage	25.1	14.6	13.4	14.6	12.2	16	3.4	1	
S. America	—	—	170	340	470	1,460	3,300	1,420	7,160
Percentage			2.4	4.8	6.6	20	46	20	
Australia	—	—	—	40	240	1,180	1,140	360	2,960
Percentage				1	8	40	39	12	
Greenland	510								510
Antarctica	3,670								3,670
Total	9,080	3,700	4,950	5,370	5,880	7,940	13,800	5,580	56,300
Percentage	16	6.6	8.8	9.5	10.4	14.1	24.5	9.9	

The total areas by continents in the two most favorable temperature belts (40°–60°) are as follows:

1. Asia . . . . . 4,280,000 square miles
2. Europe . . . . . 2,550,000 " "
3. North America . . . . . 2,500,000 " "
4. Africa . . . . . 830,000 " "
5. South America . . . . . 810,000 " "
6. Australia . . . . . 280,000 " "
7. Antarctica . . . . . nil

The dominant position taken by Asia is to some extent paralleled in Huntington's world map of "The Distribution of Human Energy on the Basis of Climate."[7] But however energetic a race may be it has not much chance in the struggle for existence if natural resources are wanting. When agricultural and mineral resources are also considered, it is seen (Fig. 8) that the greater part of Asia has a poor future.

We may now estimate the influence of this distribution of temperature belts on the density of white settlement. This can only be obtained empiri-

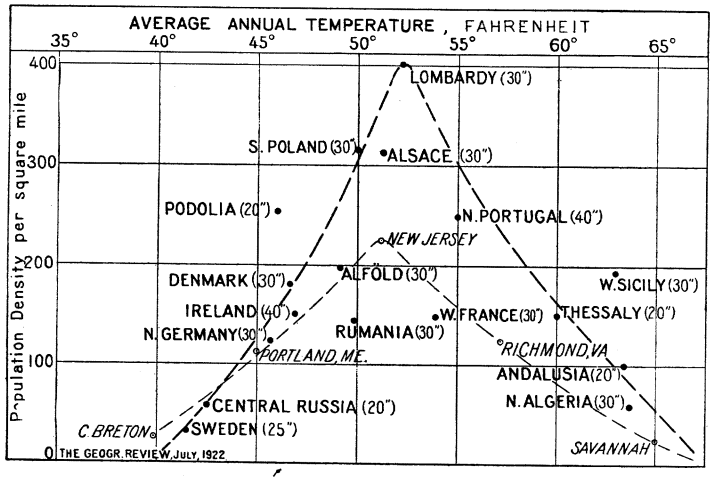

FIG. 3—Graph showing the relation between temperature and density of white population. The heavier line shows values for the European plains, coal-producing regions being omitted: the lighter line for the eastern coast of North America.

cally from data relating to the sole region where European settlement is fairly dense, that is in Europe itself.

The densest populations in Europe are distributed along the coal belt from southern Wales to Silesia. Here temperature is obviously not the main factor. Another obvious control—in this instance tending against settlement—is elevation, though here temperature is concerned as well as absence of good soils and difficulty of communications. With these two controls eliminated we find the temperature effect least complicated by other factors, that is in the *lowland regions where no coal is present.*

In Figure 3 I have charted the temperatures and population densities of almost all the plains in Europe, from the south of Sweden and central Russia with an average temperature of 42° F. to Andalusia and Algeria (which is settled by Aryan peoples) with a temperature of 63° F. These seventeen regions with one notable exception, Western France, lie fairly closely to a cuspate curve. It is to be noted that the rainfall is much the same in all these localities, from 20 to 30 inches, except in Ireland and Portugal.

[7] Huntington, *op. cit.*, p. 142.

There are, of course, considerable differences in some of the minor controls, for instance the facilities for communication and the scale of living. But, all things considered, I believe a large enough number of examples has been investigated to establish the general truth of the conclusion that a mean annual temperature of 53° F. is near the optimum for close European settlement.

On the eastern coast of North America a similar optimum occurs, though here the density of population is naturally inferior. A graph for this region is also shown in Figure 3, and it will be seen that it has much the same limits and optimum. Here the rainfall factor is nearly constant from north to south.

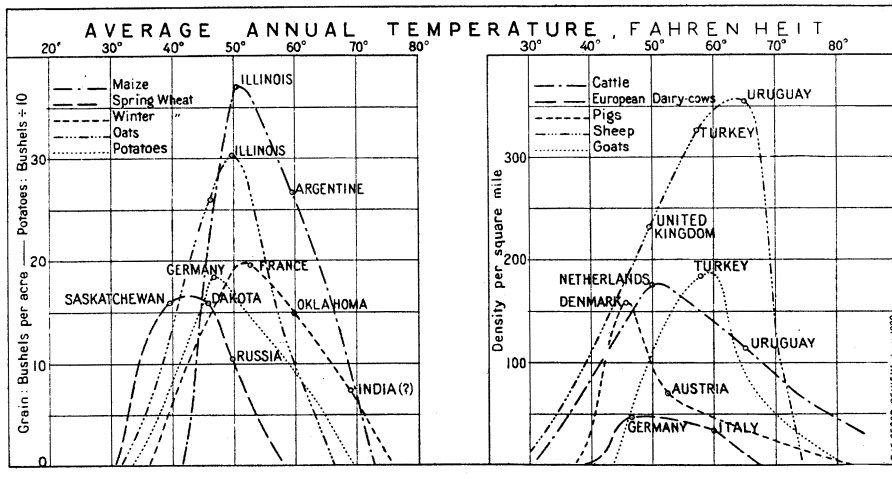

FIG. 4—Graphs showing the temperature control of production of various food crops and of stock raising. (Production data and densities from Finch and Baker.)

The temperature factor is of course variable in itself, notably as regards the annual range. While the average annual temperature is a fair criterion in general, exception must be made in the case of northern and central Asia and northern North America. Here the mean annual range exceeds 50° F. (Fig. 2), and the summer growing season is much more favorable than the annual average temperature would indicate. The summer is equal to that of many countries with an annual temperature 5° higher. I have therefore taken this into consideration, as is noted later.

Other direct controls of settlement—depending on pastoral and agricultural pursuits—may also be graphed in terms of temperature. I have found that data given in Finch and Baker's "Geography of the World's Agriculture" of great assistance in drawing up the graphs given in Figures 4–6.

The temperature controls for the main European and United States food crops of Europe and Canada and the United States are somewhat as follows. Barley grows in regions with an average annual temperature as low as

30° F. Oats, wheat (in Canada), and potatoes are also possible in such countries if the summer is relatively hot, i.e. the climate continental. The optima for barley and Canadian wheat are near 40°; for oats and potatoes near 45°; for maize in the United States near 49°; and for European wheat 51° (Fig. 4). These crops have little relative importance in regions above 60°, except the Indian wheats. It is worth noting that central Queensland, eastern Brazil, Yucatan, and Rhodesia are all regions where the climate would seem to be suitable for this winter wheat crop.

It is obvious that the temperature belt from 35° to 60° is that most favorable to grain crops (Fig. 6). However, the closest white agricultural

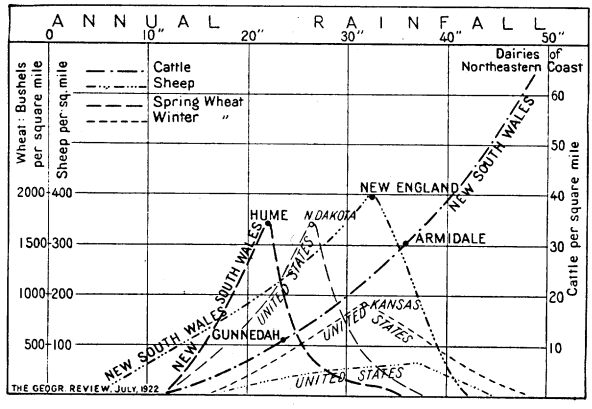

FIG. 5—Graph showing rainfall control of crop production and stock raising in New South Wales (heavier lines) and the United States (lighter lines). The curves are somewhat generalized, and it should be noted that the wheat maximum for the United States is for a whole state (Kansas), but in New South Wales for one county only.

settlement does not occur in the open prairie lands but in the mixed farming country, where the optimum temperature is distinctly higher.

The lower limit for stock is also about 30° F., sheep raising being carried on in regions with this temperature. Cattle are not much in evidence in regions below 35°, and pigs and goats about 40° (Fig. 4). According to the data in Finch and Baker's charts, the optima are somewhat as follows: pigs at 45°, cattle at about 50°, goats at 56°, and sheep at 65°. Cattle, excluding dairy cattle, range importantly through the tropics, but the other stock are not of much importance above 70° F.

RAINFALL CONTROL

If temperature is the most important control, rainfall is easily the next most important; and, if one were ignoring the race aspect, it would rise to the chief place among the physical controls of settlement.

The lower limit of important settlement can be placed at about 15 or 20 inches of rainfall per annum. In certain favored regions, where the rainy

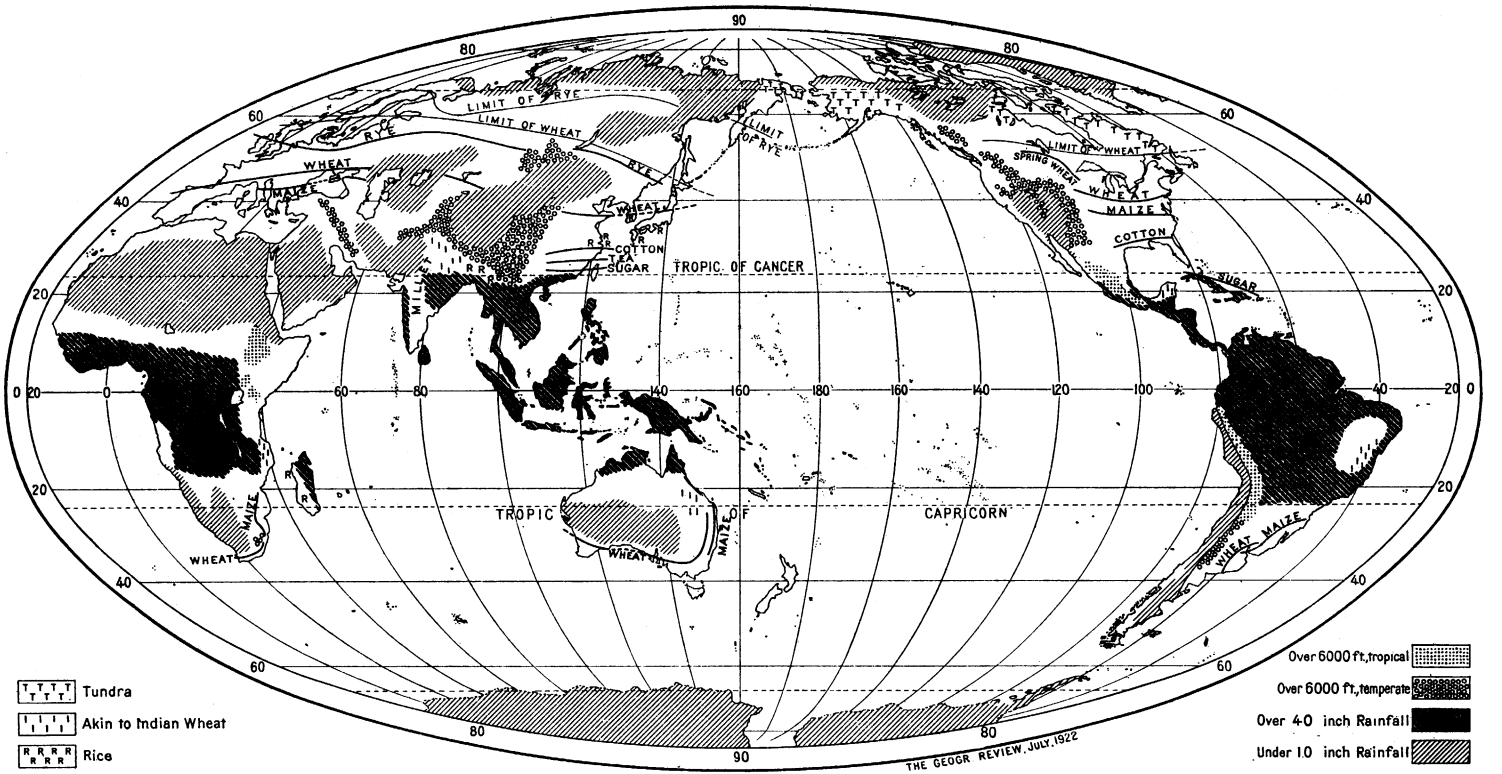

FIG. 6—Map showing in generalized form regions suitable for white settlement and crop zones of the temperate lands. Shaded areas (ruled or dotted) are largely unsuitable for white settlement.

season is very reliable and where the rain falls just at the right time, it is possible to grow wheat successfully with a rainfall as low as 10 or 12 inches. This is the case, for example, in a narrow strip of country in Western Australia, South Australia, the Mallee of Victoria, and also in parts of Oregon and the High Plains of Texas. The optimum rainfall for European settlement appears to be anywhere from 40 to 50 inches. The lower rainfall is adequate in cooler regions; the higher is not too much in regions where the evaporation is very rapid, unless it is somewhat concentrated in the summer months when the wet bulb readings are too high for comfort, as is the case for instance in Brisbane. A rainfall of over 60 inches is generally a disadvantage, though we may note such exceptions as the heavy seasonal rainfall of certain tropical regions—portions of India and Mexico, for instance—where water is stored for use in a long dry season.

In Figure 6 I have plotted the rainfall control as it affects settlement in southeastern Australia about latitude 34° S. Here there is a very uniform decrease in rainfall from 50 inches at the coast to 8 inches near Broken Hill. Dairy cattle are densest on the coast with the maximum rainfall, while cattle are unimportant in the region below 12 inches. Sheep reach a maximum density at about 32 inches, but range from 42 inches downwards. Wheat is grown between 12 and 28 inches, with a maximum at 22 inches.

It is important to note that the great cattle and sheep regions are not those semi-arid districts usually so designated in Australia, but that by far the greater number are reared in the wetter regions, where their importance is apt to be lost sight of among the many other occupations of the settlers. As regards the vast arid expanses of Australia with a rainfall below 10 inches, only a very small percentage (i.e. about two or three per cent) is grazed there, and it will never bulk importantly among the pastoral regions of the world. Similar conditions obtain in the other arid regions.

World Agriculture

From the point of view of white settlement there are four types of land surface which are unsuitable. These are the tundras of the polar regions, which are too cold for our ordinary domestic animals and also usually too dry (development of a large-scale reindeer industry remains to be seen). Secondly, and most important, the desert regions of the world, which are too dry for agriculture though a certain amount of stock can live therein. Thirdly, the rugged mountainous regions and the high plateaus of the colder belts. In tropical regions, of course, the plateaus are much more favorable for settlement, but unfortunately they are not very extensive. Huntington, however, believes that most tropical plateaus suffer from the excessive monotony of their climate.[8] The healthy *variety* of temperate regions is absent. On the other hand, Dr. Bowman writes concerning the tropical

[8] See, for instance, his article, "The Relation of Health to Racial Capacity: The Example of Mexico," *Geogr. Rev.*, Vol. 11, 1921, pp. 243–264.

plateaus:[9] "I was very much surprised to find that there are two distinct seasonal climaxes, one at the height of summer and one at the height of winter; and for the plateaus of Peru and Bolivia these climaxes endure for a period of about six weeks, with very important effects upon the life of the region." Fourthly, there are the hot wet regions of the tropics, whose natural resources are abundant but whose climate is quite unsuited for close white settlement or indeed for any white settlement requiring constant manual labor.

In Figure 6 these four types are given in a generalized form. Here the regions left blank are those suited for European settlement of some sort. Almost the whole of Europe and North America is available, about half of Asia and Australia, and relatively small proportions of Africa and South America.

In the moderately watered tropical regions a considerable population of *pastoral* whites will probably develop. In my opinion there is no prospect of a large agricultural settlement there. In temperate regions I have inserted the zones where the most important crops thrive.

In the northern hemisphere the zones, like the chief mountain ranges, run for the most part from east to west. These zones are broken by the arid and mountainous regions. In the southern hemisphere the trend lines of the continents run north and south. The crop belts more or less agree with this direction. In no case does the crop region extend to the desert areas, but a belt of stock country always occupies the margins of the desert.

The optimum of the wheat crop is near the optimum of white settlement in northern lands. In southern lands the present wheat optimum—in easily tilled prairies—is on the arid side of the optimum of white settlement.

Coal Control

Coal has been described as the "mother of industry." There is no doubt that the great industrial settlements will remain for many generations where power is cheap. The mobile hydro-electric power is not likely to be a serious rival of coal, except for certain specialized industries, for very many years.

The most striking feature of the world distribution of coal is the way in which all the major reserves are clustered along or near the 50° isotherm.[10] This coincidence may indicate that the climates of past ages have on the whole not varied very largely, and that the coal-forming vegetations grew under warm temperate conditions. Probably our present world temperatures are rather lower than usual—for we are living in the later stages of the Pleistocene Ice Age.

The total coal reserve—so far as is known at present—is approximately $7{,}937 \times 10^9$ tons.

[9] Letter to the author.

[10] In 1913 the Geological Congress at Toronto arranged for a survey of the world's reserves of coal. I have used the ensuing volumes very freely in this section of the paper.

Of this colossal amount almost 90 per cent occurs in the seven countries given below:

United States	$3{,}838 \times 10^9$ tons
Canada	$1{,}234 \times 10^9$ tons
China	995×10^9 tons
Germany	423×10^9 tons
United Kingdom	189×10^9 tons
Siberia	173×10^9 tons
Australia	165×10^9 tons
Total	$7{,}017 \times 10^9$ tons

The more one studies the resources of the world the more astounding is the position of the United States. That country is most highly favored in respect of temperature, rainfall, coal—so that the center of the world's industry and of the white population will inevitably move across the Atlantic from Europe to North America.

In the *Fortnightly Review* of February, 1918, "Politicus" discusses the effect of the coal factor somewhat as follows:

> Coal production and the birth rate are closely related; for only where there is cheap power can the densest civilized populations obtain remunerative wages in the many factories dependent on the coal. Hence the so-called "decay of the French nation" is almost entirely due to her poverty in coal and iron, which largely depended on German aggression in 1871. Almost all the growth of German population has occurred in the coal and iron towns, whose expansion has only been exceeded by the western towns of the United States. On the other hand, the German rural population was less in 1910 than in 1871. . . .

Similar results are to be expected in the other coal regions of the world, which makes Table II of vital interest in the question under discussion. In this table I have discussed separately the several well-defined coal fields which occur in some of the countries (e.g. Germany) listed.

It may be objected that we have no accurate knowledge of the geological formations through large areas of the world. This is no doubt true of much of the tropical forest country in Brazil and Africa; but here, as we have seen, close white settlement is not likely to take place owing to climatic disabilities. Much of the tropical deserts and grasslands has been prospected, at any rate to such an extent that the chances of finding a coal field rivaling those of the seven important regions is not probable. For instance, in the great area of arid Australia with hardly an inhabitant, it is safe to say that there is no likelihood of a large coal field anywhere—though some seams may be found in the northwest. When one thinks of the ubiquitous prospector for precious minerals—and of late for oil—it seems improbable that Table II will be materially altered.

I have not thought it necessary to consider other mineral deposits in this world-wide survey. Petroleum is a vital factor in our present day civilization. Distribution of its production must change within a short space of

time,[11] but no great change in settlement is likely to be effected thereby, for oil is a peculiarly transportable product. Iron ore is generally carried to the coal fields. Gold and other deposits do not lead to settlement to the

TABLE II—CHIEF COAL RESERVES OF THE WORLD

(Based on the Reports of the Geological Congress of 1913)

No.	LOCALITY	TONS ESTIMATED X 10^6	KIND OF COAL	REMARKS
1	United States Northern Plains	1,175,000	Largely lignite	Black Hills and Colorado are bituminous
2	Canada, Alberta	1,000,000	Lignite or soft coal	Bituminous in center; anthracite along west
3	United States, Rockies	1,000,000	Bituminous Anthracite	In Montana In Utah, etc.
4	China, Shansi	714,340	Anthracite	Possibly best field in the world
5	United States, Eastern	500,000	Anthracite	Chiefly Pennsylvania, Ohio, and W. Virginia
6	United States, Central	500,000	Anthracite	Chiefly Illinois and Missouri
7	Germany, Westphalia	212,000	Bituminous	
8	Germany, Silesia	166,000	Bituminous	
9	China, Yunnan, etc.	140,000	Anthracite and bituminous	Also Hunan and Szechwan
10	England (total)	125,000	Bituminous	Carboniferous
11	New South Wales	115,000	Bituminous	Permo-Carboniferous
12	Canada, British Columbia	70,000	Chiefly bituminous	Crow's Nest
13	Canada, Saskatchewan	57,400	Lignite largely	Cretaceous, etc.
14	Transvaal	56,200	Chiefly bituminous	
15	Russia, Donetz	55,000	Chiefly anthracite	
16	India, Raniganj	53,000	Bituminous	
17	Wales	40,000	Bituminous-anthracite	
18	Bohemia	40,000	Bituminous-anthracite	Pilsen and Prague
19	Victoria, Morwell	30,000	Brown coal	Tertiary
20	Colombia	27,000	Bituminous	
21	India, Hyderabad	23,000	Bituminous	
22	Scotland	22,000	Bituminous	
23	United States, Texas	21,000	Lignite	
24	Indo-China	20,000		
25	Germany, Saar	16,000		
26	Siberia, Irkutsk	15,000?		Total reserves in Siberia said to be 173 x 10^9
27	Siberia, Kuznetz	12,500	Chiefly brown coal	
28	Belgium	11,000	Bituminous	
29	France	11,000	Chiefly bituminous	
30	Spitsbergen	8,750	Bituminous	
31	Spain	8,750		

[11] David White: The Petroleum Resources of the World, *Annals Amer. Acad. of Polit. and Soc. Sci.*, Philadelphia, Vol. 89, 1920, pp. 111–134.

same extent that coal does. While the gold discoveries of 1851 accelerated the settlement of Australia, few of the large number of immigrants ultimately engaged in gold mining—they turned to farming, etc. In Australia today it has been estimated that only about 120,000 people dwell in gold fields which are remote from agricultural districts.

Location Factor

We have considered the three major factors determining close European settlement. Of those remaining, soil and communications are perhaps the chief. Both of these depend largely on elevation: almost all the largest areas of good soil and of easy communication are plains below 2,000 feet elevation. Speaking generally, elevation is a disadvantage, for it always implies heavy transport difficulties. Tropical plateaus are an improvement on tropical lowlands for white settlers inasmuch as they come nearer to the optimum temperature; but this is expressed by the temperature scale in our estimate of the value of the region under consideration. We can therefore use a *location scale* ranging upwards from an optimum at sea level and trust to the temperature control to express the healthier conditions of tropical plateaus.

Other Factors

It will be found that almost all the factors influencing human settlement are based on the four considered above. Health is controlled primarily by temperature and humidity—of which the latter is closely related to rainfall. Agriculture is concerned with rainfall and temperature. A rich soil is not vital in these days of fertilizers. Thus in the Australian Mallee and other regions of an extremely sandy nature an addition of superphosphate gives a payable wheat yield. In the future, artificial manures will be of increasing importance; but the natural controls of temperature and rainfall can never be altered.

Irrigated regions are perforce not properly represented in this scheme. Except in Egypt and Mesopotamia they are not likely to build up vast populations in desert countries. In Australia, for instance, the irrigated lands form only one part in ten thousand of those which require more rainfall, and this small proportion will never be sufficiently increased to be of much importance.

Pastoral industries are determined almost wholly by rainfall and not by temperature; for some varieties or other of cattle, sheep, or allied animals range throughout the continents, excluding only the permanent ice caps and the dense tropical forests. Industrial settlement, the great feature of modern life, is dependent essentially on temperature and coal. We have noted that there are practically no coal fields in arid regions.

It is impossible to discuss every factor. Fisheries, which from the most ancient times have been a factor of local importance, are ignored, and they lead to some fairly important populations today.

The psychical factor, for instance the influence of religion and of genius, in determining man's environment is an aspect which does not lend itself to quantitative representation.

The Econograph

The most difficult feature in this research was to compare the values of the four major controls of white settlement. I was only able to arrive at what seems a fairly satisfactory conclusion in regard to the order of importance of the factors of temperature, rainfall, coal, and location by a method of trial and error. The problem may be simplified by considering the effect of location and coal supply first.

The location factor is of much less importance than the other three. As long as the regions are on the average below 1,500 feet or so this factor is not vital as regards communications, etc. Above 1,500 feet a handicap is introduced; but only in a few cases does this factor exert paramount influence over regions, though admittedly it determines certain important ports and junction towns. We may, therefore, for a time ignore the location factor.

With regard to coal it is only possible to see how this factor influences the population of a country by comparing it with an adjoining country not blessed with this asset.

Table III—Influence of Coal on Density of Population

Country Rich in Coal		Small or No Coal Supply		Ratio
Bohemia	315	Hungary	160	1.9
Germany	324	France	191	1.7
Poland	193	Western Russia*	94	2.0
Britain	460	Ireland	140	3.2

* Four adjacent provinces equal in area to Poland.

The above comparisons are by no means exhaustive, and some striking exceptions, such as Italy, can be found; but they serve to show that, under present conditions in Europe, the presence of abundant coal and the resulting industries have about doubled the population in the countries so favored.

We are now faced with the following problem. We have three paramount factors, temperature, rainfall, and coal, which practically control the white settlement of today with the exception of a few mining districts. We have a continent, Europe, where these factors have operated for so long a period that it may be assumed that under present economic conditions the population is distributed largely in direct response to these factors.

I have divided Europe into eight natural regions whose population density varies greatly, from that of the British Isles to that of the Tundra. Assuming that one knew the exact relative values of the factors temperature and

rainfall one could express this as an area (i.e. temperature x rainfall) which could be equated with the population resulting therefrom.

Since the density of population depends directly on the variables temperature and rainfall, the theory of variation tells us that we may use the product, temperature factor x rainfall factor, to represent the density. This can be expressed as an area; and this area (triangle *A B O* in Fig. 7) forms the basis of the empirical graph which I use to compare the seventy-four regions of the world.

My method has been to arrive at the relation of the temperature factor to the rainfall factor by assuming various values and testing them against the actual population map of Europe.

It was logical to start off by giving the optimum temperature and optimum rainfall equal values. Hence a country with an average temperature of 55° F. and an average rainfall of about 50 inches would be represented by a right angled triangle with two sides of equal length. If in addition it had the optimum amount of coal of some 200 x 10^4 tons per square mile, then this triangle would be doubled in area by adding another axis to the right of equal value to the other two.

We may then draw corresponding triangles or quadrilaterals for the eight regions of Europe (using the above dimensions for the optimum values). The areas of the eight figures will stand in a certain relation to each other. If our premises are correct, these areas will be proportional to the actual populations of the regions concerned. If our factors are wrongly related, then the population densities (or isopleths expressing the populations) will not at all agree with the areas of our figures.

This is the method of trial and error which I have used. The "test" areas using equal lengths for the temperature, rain, and coal axes did not give isopleths corresponding to the actual population lines, which should result from the plotting of such axes in the manner described. If, however, the relation shown in Figure 7 be made use of, where the temperature control is given double the weight of the rainfall, while the coal factor, if extremely large, may double the area, then the resultant economic graphs for certain fully developed regions agree fairly with their respective populations.

The writer is prepared for some adverse criticism of this method, but he feels that there is much to be gained by the use of these comparative graphs. He would remind readers that the introduction of a similar method of comparing climates by the climograph[12] has led to a number of interesting papers on comparative climatology, in which moreover useful suggestions for improving this graphic method have been made. The writer hopes for the same happy result from the present paper.

The "econograph" is a rectangular figure formed on four axes which represent, respectively, the average annual temperature, the average annual rainfall, the average elevation, and the (estimated) total coal reserve of the region.

[12] *Geogr. Rev.*, Vol. 4, 1917, pp. 401–403.

The ideal region would have an econograph like that shown in Figure 7. The temperature would be 55° F.; the rainfall 50 inches; the region would be at sea level; and the coal supply 200 x 10^4 tons per square mile. It will be seen that the temperature and rainfall give the triangle *A B O*, while the presence of a large coal supply doubles this by adding the triangle *A O D*. The location effect is shown by the small area below the line *B D;* it is not of much importance save that if a region be mountainous, this area almost disappears.

In the scale used the area of the ideal econograph occupied 1,000 units. All the seventy-four regions were below this ideal, though Britain and North China each totaled 770 units. It is my purpose to show that the area of the econograph represents the habitability of the region as closely as one can expect to assess it in the present state of our knowledge.

In Table IV I have recorded the economic factors. The first column gives the area of the region. The next four columns can be used to plot the econographs according to the scales on the ideal graph.

Variation of the shape of the econograph may be studied with profit. A symmetrical graph, like that of Britain, indicates that a region is well equipped for agricultural or industrial occupations. If only the left side is present, it is chiefly an agricultural or pastoral region, e.g. Central Russia. In a few cases the right side predominates, as in the Utah region, which means that the coal reserves are likely to be of greater value than the agricultural resources. Where the lower triangle (below the horizontal axis) is large the region possesses extensive lowlands and is likely to have large areas suited for intense cultivation, e.g. Southern Russia. Where it is small the country is elevated and usually not well suited for agriculture, e.g. Norway.

Somewhat similar indications are given by the length of the diagonals (or axes). If the upper axis is long, then the region will have a comfortable climate, e.g. Britain or Southern California; and if it be short, the converse is the case, e.g. Norway or most tropical regions. A short axis to the left is unfavorable for white farming but is often suitable for a pastoral occupation. A wet mountainous region, where hydro-electric energy is usually plentiful, is shown by a short lower axis combined with a long axis to the left, e.g. Southern Chile. The desert regions have a characteristic elongated shape ranging from the moderately arid type, such as Southern California, to the almost entirely useless types of the Tundra or the Thar.

World Isoiketes

If now the numbers representing the areas of the regional econographs, and thus the habitability of the regions, be plotted on a map of the world (as in Fig. 8), we can draw lines through the numbers and form a sort of contour map. To such a line I gave the name "isoikete" (from *οἰκητός*, habitable).[13]

[13] *Geogr. Rev.*, Vol. 8, 1919, p. 112.

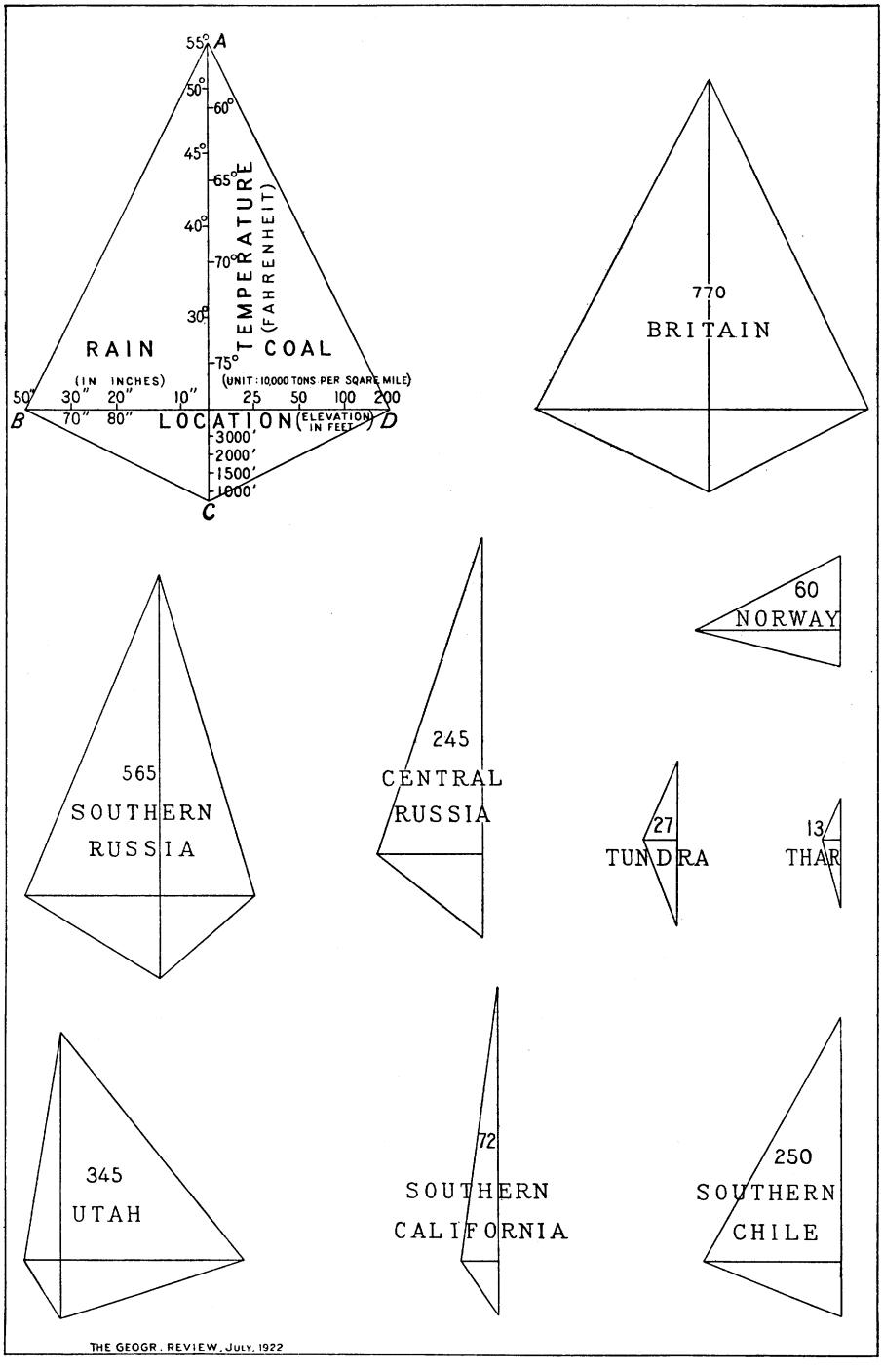

FIG. 7—The standard or ideal econograph and examples of its application. The econograph is an empirical graph based on the four major controls of settlement. Its area is approximately proportional to the habitability of the region concerned which for the ideal region is taken as 1000 units. The standard graph is represented above by the figure *A B C D* (the crossing of the axes of the coördinates is the point *O*). Figures within the regional graphs show the area and thus the relative habitability of the regional illustrations shown.

TABLE IV—ECONOMIC FACTORS OF THE REGIONS

REGION	AREA (square miles x 10^3)	AVERAGE ANNUAL TEMP. (degrees F.)	ANNUAL RAIN-FALL (inches)	AVERAGE ELEVA-TION (feet)	TOTAL COAL RESERVE (tons x 10^4)	COAL PER SQ. MILE (tons x 10^4)	AREA OF ECONO-GRAPH (1,000 units = max.)
Europe							
British Isles	120	50	40	600	190	160	770
Franco-Prussia	422	50	30	600	250	60	620
Poland (with S. W. Russia, etc.)	400	50	28	600	200	50	565
Central Russia	1,200	45*	20	600	55	4	245
Mediterranean	545	60	20	1,500	—	—	210
Northern Russia	461	38	15	600	—	—	65
Norway	125	28	38	3,000	—	—	60
Tundra	600	29*	9	600	—	—	12
Asia							
Northern China	360	55*	30	1,500	714	200	770
Japan	300	55	40	2,000	—	—	484
Southern China	588	68	65	2,000	140	24	288
Mediterranean	158	60	18	3,000	—	—	180
Siam	750	75	60	1,000	20	3	136
Manchuria	940	30*	20	1,500	—	—	120
Western Siberia	768	35*	15	600	13	2	120
Ceylon	25	80	30	1,500	—	—	78
Deccan	588	75	20	1,200	—	—	72
Persia	1,000	55	10	3,000			66
Eastern Siberia	740	30*	12	2,000	15	2	45
East Indies	800	80	80	2,000	—	—	43
Aral	1,100	50*	6	600			40
Altai	820	30*	15	4,500			35
Tibet	2,100	30*	12	12,000	—	—	30
Tundra	3,220	20*	10	600	—	—	27
Arabia	1,372	75	10	1,500			20
Tarim	750	55*	6	3,000			20
Thar	263	80	5	600			13
Northern India	870	75	40	1,000	76	9	140
Australia							
Victoria	172	55	30	1,000	30	18	575
Eastern Coast	98	65	40	2,000	115	110	574
New Zealand	104	50	50	2,000			430
Tasmania	26	50	40	1,200			400
Swanland	172	60	20	1,000			225
Queensland	282	73	25	1,000			143
Lachlan	245	65	15	500			119
Northern Coast	578	80	25	800			70
Southern arid	835	65	7	1,200			40
New Guinea	343	77	100	2,000			21
Northern arid	565	75	9	1,000			16

* Temperate region with hot (continental) summer; 5° F. added on econograph axis.

TABLE IV—ECONOMIC FACTORS OF THE REGIONS (*continued*)

REGION	AREA (square miles x 10^3)	AVERAGE ANNUAL TEMP. (degrees F.)	ANNUAL RAINFALL (inches)	AVERAGE ELEVATION (feet)	TOTAL COAL RESERVE (tons x 10^4)	COAL PER SQ. MILE (tons x 10^4)	AREA OF ECONOGRAPH (1,000 units= max.)
Africa							
Natal	140	60	30	3,000			300
Transvaal	264	62	20	3,000	56	21	273
Cape	128	59	20	1,500			225
Rhodesia	1,250	72	40	3,000			180
Madagascar	227	72	40	1,500			136
Algeria	390	68	20	2,000			125
Congo	1,587	78	70	1,000			76
Uganda	770	75	30	3,000			68
Sudan	2,080	79	35	1,500			65
Kalahari	500	63	8	3,000			48
Northern Sahara	2,466	68	20	1,000			16
Southern Sahara	1,338	78	5	1,000			10
North America							
Northeastern states	747	50	35	1,000	1,000	135	755
Inland plains	592	60	20	2,300	1,175	200	675
Alberta	630	40*	15	2,500	1,000	170	420
Utah	250	45	10	5,000	500	200	345
Southeastern states	486	65	40	1,000	21	4	326
Eastern Canada	960	40*	27	1,000			315
Oregon	246	55	25	3,000			315
Southern Rockies	510	65	12	5,000	500	100	300
British Columbia	345	38	40	2,500	70	20	286
Central America	592	70	60	3,000			165
West Indies	100	78	50	1,000			120
Southern California	444	63	10	2,000			72
Tundra	1,910	15*	12	1,000			15
South America							
Uruguay	750	65	35	1,000			315
Southern Chile	131	45	70	3,000			272
Western Argentine	525	60	20	800			210
Central Chile	78	55	15	3,000			184
Andean plateau	525	63	15	8,000			112
Colombia	945	78	40	1,000	27	3	95
Central Brazil	1,820	78	70	1,000			91
Eastern Brazil	328	75	25	1,000			78
Amazons	1,969	80	80	500			65
Northern Chile	210	60	3	5,000			60
Patagonia	78	45	10	1,200			45

* Temperate region with hot (continental) summer, 5° F. added on econograph axis.

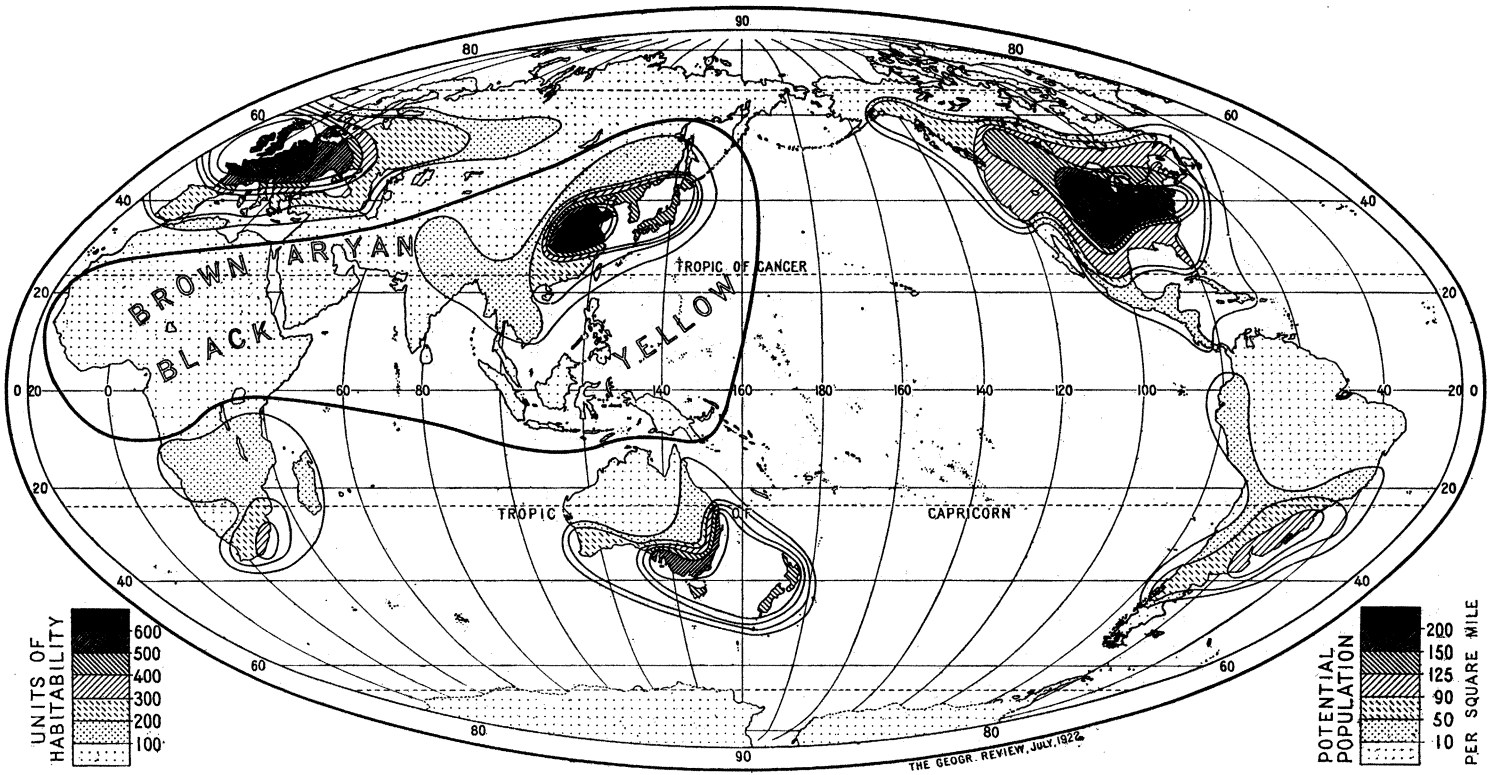

FIG. 8—The distribution of future white settlement according to the economic value of the world regions (see Fig. 1 and Table IV). The area within the heavy black line is not available for white settlement but has been treated uniformly here. The facts of the distribution shown in this figure may be expressed by degree of habitability, shown by "isoiketes" (see legend to the left) where the optimum of habitability is 1000, or by the corresponding potential population density (see legend to the right).

Figure 8, drawn in this fashion, presents many points of interest. There are three first-class centers of (white) habitability, two of the second class, besides many areas in North America around the major centers. These are shown in Table V.

TABLE V—POTENTIAL REGIONS OF CLOSE WHITE SETTLEMENT

CLASS	UNITS OF HABITABILITY, 1000 = max.	REGION AS DEFINED IN FIGURE 1	PRESENT SETTLEMENT
I	770	British Isles	Closely settled
	620	Franco-Prussia	Closely settled
	770	Northern China	Not available for whites
	756	Northeastern states of the United States	Moderately settled
	675	Inland plains of the United States	Sparsely settled
II	565	Poland, Austria, etc.	Closely settled
	575	Victoria (Australia)	Moderately settled
	565	Eastern coast of Australia	Moderately settled
III	484	Japan	Not available for whites
	430	New Zealand and Tasmania	Sparsely settled
	420	Alberta	Sparsely settled
IV	315	Uruguay	Moderate settlement
	300	Natal	Moderate settlement (not wholly available)
	345	Utah	Dry, sparsely settled
	326	Southeastern states of the United States	Moderately settled
	315	Eastern Canada	Sparsely settled
	315	Oregon	Sparsely settled
	300	Southern Rockies	Dry, sparsely settled
V	286	British Columbia	Sparsely settled
	288	Southern China	Not available for whites
	250	Southern Chile	Sparse
	245	Central Russia	Fairly close settlement
	225	Swanland	Sparsely settled
	213	Transvaal	Sparsely settled
	210	Western Argentine	Sparsely settled
	210	Mediterranean	Closely settled

The first eight regions (Classes I and II) in Table V are all endowed with a plentiful coal supply. In the third class come two regions, Japan and New Zealand, with poor coal supplies but excellent climatic controls. The enormous coal supply of Alberta is balanced by its long winter, so that it appears rather low down amid the most attractive regions.

TABLE VI—REGIONS OF POTENTIAL MODERATE WHITE SETTLEMENT

CLASS	UNITS OF HABITABILITY	REGION	REMARKS
VI	180	Rhodesia	Sparsely settled
	180	Anatolia	Largely occupied
	168	Central Chile	Largely occupied
	165	Central America	Largely occupied
	143	Queensland	Sparsely settled
	140	Northern India	Not available
	136	Siam	Not available
	136	Madagascar	Not available
	125	Algeria	Largely occupied
	120	Western Siberia	Sparsely settled
	120	West Indies	Largely occupied
	120	Manchuria	Not available
	119	Lachlan	Sparsely settled
	112	Andean plateau	Largely occupied

In this class Rhodesia, central Queensland, Western Siberia, and the Darling Basin offer large areas for settlement which may be used for ranching or, in places, for dry farming.

The remaining regions of the world comprise the tundras, deserts, and hot wet countries where even moderate white settlement is unlikely. A considerable development of the pastoral industry with sparse white settlement is of course probable in the more favorable areas.

TABLE VII—APPROXIMATE DENSITY VALUES FOR ECONOGRAPH AREAS

ECONOGRAPH AREA	POPULATION DENSITY PER SQUARE MILE
600 units	200
500	150
400	125
300	90
200	50
100	10

EUROPE AS A CRITERION

The only large region where white settlement has taken place for centuries is of course the continent of Europe. From all the European countries emigration has removed the surplus populations; and, though we cannot describe the continent as "saturated," it is the only one which approaches that condition.

In Figure 9 is shown the theoretical distribution of population in Europe by isoiketes compared with the present actual distribution. We see at once that

there is a strong resemblance between the isoiketes and the population lines. Both center about London from whence they form concentric loops about an axis reaching to Western Siberia. The 100 isoikete agrees quite closely with the 10 population line if the latter be inserted between the 2 and 26

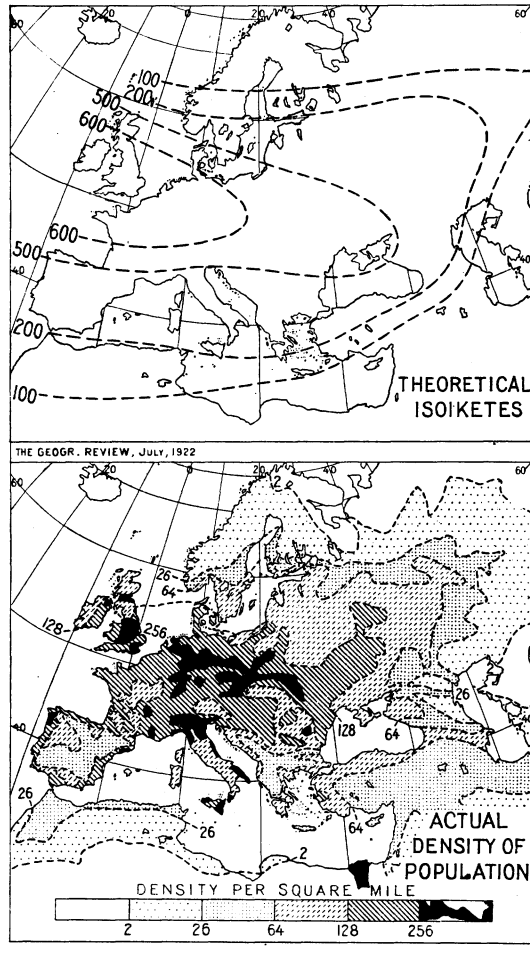

FIG. 9—The actual population density of Europe compared with the theoretical isoiketes (lines of "habitability").

lines. In the same way the 200 isoikete agrees fairly with the 50 population line, if it be inserted. The 500 isoikete is near the 150 population line, and the 600 isoikete is not far from the 200 line except in Galicia.

Plotting on a graph the European density of population and its corresponding isoikete, we can interpolate for the regions of moderate habitability, which do not occur in Europe. This gives us Table VII.

Using these factors we can arrive at a probable answer to the question,

"How will the white population of the world be distributed when the empty continents are occupied to the extent that Europe is at present?"

Conclusions

Distribution of Population

Using the ratios indicated in Table VII, we may hazard an estimate of the white populations which will cluster around the five world centers of Chicago, London, Sydney, Buenos Aires, and Durban. When the surrounding region shall have reached the condition of western Europe (with a density exceeding 100 per square mile) we may expect populations of the order given in Table VIII.

Table VIII—Potential Populations in the Chief Areas of White Settlement

Region (Fig. 1)	Area in Square Miles	Estimated Density per Square Mile	Total Population
North American Regions			702 millions (52%)
Northeastern states	747 x 10^3	400	298
Inland plains	592	200	118
Alberta	630	100	63
Utah	250	100	25
Southeastern states	486	100	48
Eastern Canada	960	100	96
Oregon	246	100	24
Adjoining regions		below 100	30
European Regions			386 millions (29%)
Britain	120 x 10^3	500	60
Franco-Prussia	422	300	126
Poland, etc.	400	200	80
Adjoining regions		below 100	120
South American Regions			115 millions (8.5%)
Uruguay, etc.	750 x 10^3	100	75
Adjoining regions		below 100	40
South African Regions			82 millions (6%)
Natal	140 x 10^3	100	14
Rhodesia	1,250 x 10^3	(40)	50
Adjoining regions		below 100	18
Australian Regions			62 millions (4.5%)
Victoria	172 x 10^3	180	29
Eastern coast	98 x 10^3	180	18
Adjoining regions		below 100	15

The total of these regions is 1,347,000,000. Distributed according to political control we have 377,000,000 (28 per cent) in the British Empire, 513,000,000 (38 per cent) in the United States, 457,000,000 (34 per cent) in other countries.

Conurbations

Assuming that an adequate food supply is forthcoming, we may briefly consider how these vast populations will settle in the five major areas.

Professor Geddes, who looks forward to a period of more orderly design, has pointed out that in the British industrial regions the cities at present merge into great "disorderly conglomerations."[14] In England, for instance, there are two great clusters, "Greater London" and what he terms "Lancaston." The latter, extending from Liverpool to Leeds, is already 100 miles wide. He points out that five other conurbations are arising. These are the Scottish center (Glasgow-Edinburgh), the Newcastle center, the Sheffield center, the Birmingham center, and the South Wales center.

Lille and Essen are two continental examples which in the near future will unite via Antwerp and Liége. The Pittsburgh district is a forecast of the intense settlement which will arise in the eastern United States. Even in Australia the rise of such towns as Cessnock (4,000) within the last few years points to a conurbation around Newcastle. This will unite with Sydney and spread down the coast to the great Bulli coal field.

Food Supply and Population Increase

Where is the food coming from to feed these industrial centers? Most people know of the huge granaries of Russia, the United States, India, etc., but fail to realize that already their huge populations permit of only limited export—before the war only about one-sixth of the total wheat production of each of these countries was exported (Table IX). Canada, Argentina, and Australia are exporting considerable percentages at present; but how long can this be maintained in the face of their own growing populations?

Table IX—Chief Wheat-Exporting Countries, Average Production and Export 1911–1913*

(In millions of bushels)

	Production	Export
Russia	727	128
United States	705	116
Canada	229	111
Argentina	156	101
India	370	60
Rumania	88	54
Australia	89	52

* G. B. Roorbach: The World's Food Supply, *Annals Amer. Acad. of Polit. and Soc. Sci.*, Philadelphia, Vol. 74, 1917, pp. 1–33. See also J. Russell Smith: The World's Food Resources, New York, 1919.

It has been estimated that before the war the United Kingdom and Belgium produced only 53 per cent and 57 per cent of their respective food requirements. To a less degree Germany and even France were dependent on outside sources. The closely settled regions of the East—India, China

[14] Patrick Geddes: Cities in Evolution, London, 1915.

and Japan—also are already anxious as to future food supplies. It is indeed a vital problem for the world as a whole and is of more immediate interest than most people realize.[15]

Let us consider the North American region of settlement with its potential 700 millions. The population of the United States has been doubling itself approximately each thirty years during the last century. It was 25 millions in 1850, 50 millions in 1880, and 100 millions in 1910. If this rate of increase continue, it will have grown to 700 millions in less than 100 years!

The world as a whole has doubled its population during the last ninety years. If the rate for North America drops to this figure, then it will take about 270 years to reach 700 millions.[16]

If we consider the time which it will take the Australian population of 5 millions to grow to 62 millions we find that it amounts to 100 years on the more rapid rate—which obtains at present—and to 320 years on the slower rate. These are much the same periods as deduced for the United States.

The Commonwealth Statistician (G. H. Knibbs) concludes his voluminous report on the 1911 census with the following pertinent remarks (p. 455):

> The earth's population may be taken . . . as 1,500 millions and its land area (excluding Polar regions) at 33,000 million acres. If we could raise 22.8 bushels of food corn per acre per annum, the total yield would only be 752,400 million bushels. The food consumption (per person) per annum is about equivalent to 5.7 bushels—which on the above computation would feed 132,000 million people.
>
> At the rate of increase of population of 0.01 per annum (somewhat less than the rate for all countries which have accurate statistics), it would require only 450 years to exhaust the food requirements mentioned. . . . The fundamental element in Malthus' contention is thus seen to be completely established.

I have shown what I deduce to be the distribution of the white peoples during the next two centuries. According to it we may expect an increase of 600 millions gradually to occupy North America; 100 millions in South America, and over 50 millions in southeastern Australia and also in South Africa. The future of the Indian and colored races I have not attempted to discuss in this paper. Already they amount to over 1,000 millions, and one can hardly estimate their increase in numbers in two centuries; for with the spread of sanitation and of law and order the natural increase of population throughout Africa and Asia is not likely to diminish.

Yet a general decline in the birth rate would seem to be the only answer to the statistical argument which I have quoted. It is difficult to imagine a crop (at present unknown) more valuable than wheat, and covering every acre of land surface. A vast world struggle between higher civilizations with a low birth rate and lower civilizations with a high birth rate seems to be foreshadowed. This would seem to be inevitable within the next two centuries if the white race is to maintain its dominant position.

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[15] On the general problem see M. Aurousseau: The Distribution of Population: A Constructive Problem, *Geogr. Rev.*, Vol. 11, 1921, pp. 563–592.

[16] Compare E. M. East: The Agricultural Limits of Our Population, *Scientific Monthly*, Vol. 12, 1921, pp. 551–557.